Using Passive and Active Acoustics to Examine Relationships of Cetacean and Prey Densities

Simone Baumann-Pickering
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0205
phone: (858) 534-7280 fax: (858) 534-6849 email: sbaumann@ucsd.edu

Award Number: N00014-15-1-2587
http://baumann.ucsd.edu

LONG-TERM GOALS

The long-term goal is to identify if sound is produced or modulated by cetacean prey species in the water column using passive and active acoustic methods. Given the universal presence of backscatter organisms in all oceans and the likely relevance of these sound patterns to species involved and their predators, this is directly relevant to naval operations. It can a) be used in long-term monitoring leading to improved cetacean predictability and mitigation during naval exercises and b) shed light on the relationship of acoustic backscatter and ambient sound across time and space, which is relevant to the U.S. Navy sonar community.

OBJECTIVES

The proposed work aims to understand origin and variability of ambient sound from 50 Hz to 50 kHz. We hypothesize that forage species in the water column contribute either through sound modulation or production to the marine soundscape with daily, lunar, and seasonal patterns. We aim to document how presence and intensity of certain sounds relate to spatio-temporal variability of active acoustic backscatter strength. Additionally, several marine mammal species are predators of deep-scattering layer (DSL) species as well as krill. We intend to investigate if passive acoustic marine mammal detections are related to increased backscatter strength and possible sound modulation or production of forage species. Specifically, during this project, we will address the following hypotheses:

H1: Forage species modulate or produce sounds that can be monitored passive acoustically.

H2: Long-term spatio-temporal variability of active acoustic backscatter strength and passive acoustic ambient sound are related.

H3: Predator (cetacean) presence and behavior is related to prey (DSL and krill) density and behavior, measurable active and passive acoustically.

APPROACH

Sounds produced by forage species and predators will be identified and quantified on passive acoustic sensors and acoustic backscatter strength (or organismic group biomass when feasible) will be determined on active acoustic sensors. The data will be collected on two stationary moorings (integrated with the California Current Ecosystem Long-Term Ecological Research mooring sites, CCE-LTER) over several years and intermittently on an acoustic-optical-profiling float over several days with a concurrent passive and active acoustic spatial survey and net sampling. Additionally, data collected from an Acoustic Doppler Current Profiler (ADCP) mounted on a glider running on two California Cooperative Oceanic Fisheries Investigations (CalCOFI) lines and passive as well as active acoustic data collected during quarterly CalCOFI surveys on those two lines will shed light on spatio-temporal variability of cetaceans and forage species. The relationship of intensity of acoustic backscatter and ambient sound across time and space will be investigated.

Collaborators in this effort are Drs. David Checkley, Julian Koslow, Uwe Send, and Dan Rudnick at Scripps Institution of Oceanography, UC San Diego, and Dr. David Demer at NOAA Southwest Fisheries Science Center.

WORK COMPLETED

A preliminary experiment was carried out (see section Results) that documented sound production by backscatter organism within the DSL.

A new acoustic and optical profiling float that will allow *in situ* recordings at distinct depths is under development. An Argo float (SOLO-II) with a small passive acoustic recorder (miniHARP) and an active Acoustic-Optical Sampler (AOS) is being coupled (Figure 1).

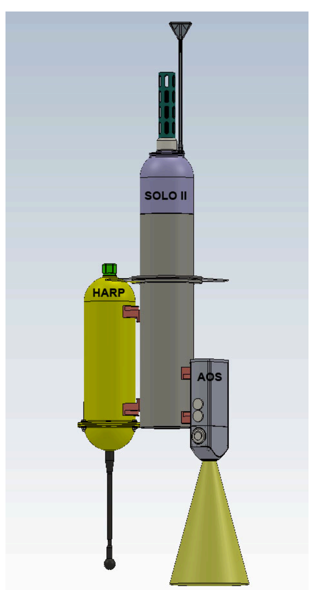

Figure 1. Acoustic-optical profiling float with miniHarp and AOS on SOLO-II.

RESULTS

Mesopelagic prey measurements

The DSL, comprised of a large number of plankton and nekton species of a variety of sizes, undergoes a diel vertical migration in multiple organismic layers from deeper water during the day (several hundreds of meters) to epipelagic waters during the night (less than 150 meters, Figure 2) (e.g. Enright & Hamner 1967). This large-scale migratory behavior is likely driven by daytime predator avoidance and nighttime feeding in food-rich surface waters (e.g. Angel 1985).

Passive acoustic data collected at various sites in the North Pacific with long-term, autonomous, bottom-moored, omni-directional recorders (High-Frequency Acoustic Recording Packages, HARPs (Wiggins & Hildebrand 2007), anchored at 600-1000 m depth), show diel patterns in ambient sound. The most common pattern at many sites occurs near sunset, exhibiting increased spectrum levels at two frequency bands – 200-800 Hz (Figure 2) and 2-6 kHz. Additionally, at some locations, a broadband acoustic signal with bandwidth up to 60 kHz appears at night with crepuscular peaks (Baumann-Pickering et al. 2011). Nighttime depth of the DSL shows a dependency on the lunar cycle, remaining deeper during periods with strong illumination, likely to avoid predation (Angel 1985). Similarly, maximum received levels of ambient sound during full moon periods are substantially lower than during new moon phases with low light situation.

During a recent preliminary experiment, Drs. Checkley, Demer, and Baumann-Pickering investigated if DSL organisms create sound, particularly during periods of dusk and dawn. Over several nights in summer 2015, underwater sound was recorded in the San Diego Trough using a HARP (10 Hz to 100 kHz), suspended from a drifting surface float. Acoustic backscatter from the DSL was monitored nearby using a calibrated multiple-frequency (38, 70, 120, and 200 kHz) split-beam echosounder (Simrad EK60) on a small boat. DSL organisms produced sound, between 300 and 1000 Hz, and the received levels were highest when the animals migrated past the recorder during ascent and descent (Figure 2). Active acoustic information collected by this multi-frequency scientific echosounder on target strength and target position can be used to classify individual targets. Frequency-dependent backscattering, allowing for dB differencing analysis, can be used to distinguish broad taxonomic groups such as crustaceans, squid, and fish with swim bladders (Greenlaw & Johnson 1983, Kalish et al. 1986, Holliday & Pieper 1995, Davison 2011).

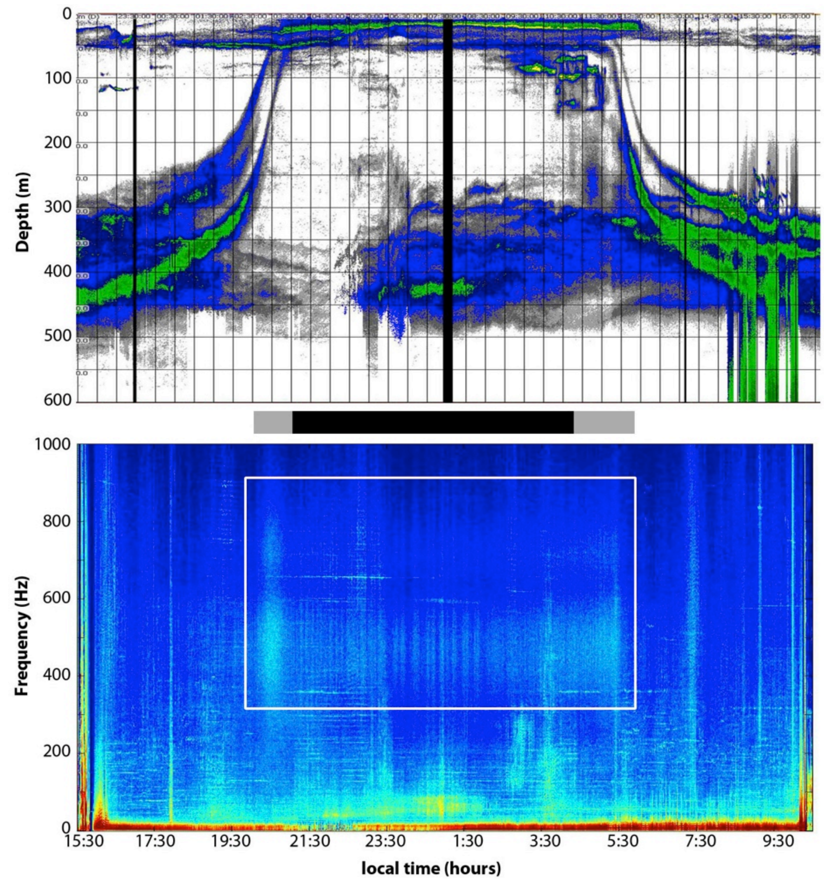

Figure 2: Active (top) and passive acoustic recordings (bottom) from July 21-22, 2015 in the San Diego Trough. Top: Backscatter strength at 38 kHz shows DSL ascent in multiple layers during dusk from deep water to the surface and descent during dawn back to depth (center bar: grey=twilight, black=nighttime). Bottom: Increased sound pressure levels between 300-600 Hz and 700-1000 Hz throughout the night with highest levels as DSL organisms migrate past the hydro-phone (200 m depth).

IMPACT/APPLICATIONS

Ambient sound patterns of biological origin in a frequency range relevant to US naval sonar may alter sonar ranges with a diel, lunar, and seasonal pattern, and likely geographic area. Additionally, organisms in the water column are “bio-clutter” targets that alter sound propagation on these time scales, dependent on the target behavior and density. The identification, description, and quantification of sound patterns and the behavior of the corresponding organisms are of relevance to the US Navy sonar community.

Scatterer, especially krill and DSL species, are prey items for large predators, of which marine mammals are of particular interest to the US Navy. Prey is likely a driver and indicator for marine mammal distribution, abundance, and behavior. The possibility of long-term, autonomous monitoring of prey distribution and behavior using combined methods of active and passive acoustics may lead to an increased predictability of marine mammal presence for mitigation of Naval operational impacts.

RELATED PROJECTS

ONR DURIP N00014-15-1-2858 PI Širović
The instrumentation grant was given to purchase acoustic moorings for integrated cetacean-prey studies. Knowledge gained in this project will be useful in interpreting data collected with the new moorings.

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